Long Term Resource Monitoring Program

COMPLETED

Technical Report

95-T003

Modifications to the Upper Mississippi River and Their Effects on Floodplain Forests

32

February 1995

5A

Cover graphic by
Mi Ae Lipe

Modifications to the Upper Mississippi River and Their Effects on Floodplain Forests

by
Yao Yin
The University of Tennessee
and
National Biological Service
Environmental Management Technical Center
575 Lester Avenue
Onalaska, Wisconsin 54650

John C. Nelson
Illinois Natural History Survey
LTRMP Pool 26 Field Station
4134 Alby
Alton, Illinois 62002

Prepared for

National Biological Service
Environmental Management Technical Center
575 Lester Avenue
Onalaska, Wisconsin 54650

February 1995

The Environmental Management Technical Center issues LTRMP Technical Reports to provide Long Term Resource Monitoring Program partners with scientific and technical support.

National Biological Service
Environmental Management
Technical Center

CENTER DIRECTOR
Robert L. Delaney

SCIENCE ADVISOR
John W. Barko

INFORMATION AND TECHNOLOGY
SERVICES DIRECTOR
Norman W. Hildrum

MANAGEMENT APPLICATIONS AND
INTEGRATION DIRECTOR
Kenneth S. Lubinski

REPORT EDITOR
Madelon M. Wise

Mention of trade names or commercial products does not constitute endorsement or recommendation for use by the National Biological Service, U.S. Department of the Interior.

The National Biological Service . . . gathering, analyzing,
and sharing the biological information necessary to support the wise
stewardship of the Nation's natural resources.

Printed on recycled paper

Preface

The Long Term Resource Monitoring Program (LTRMP) was authorized under the Water Resources Development Act of 1986 (Public Law 99-662) as an element of the U.S. Army Corps of Engineers' Environmental Management Program. The LTRMP is being implemented by the Environmental Management Technical Center, an office of the National Biological Service, in cooperation with the five Upper Mississippi River System (UMRS) states, Illinois, Iowa, Minnesota, Missouri, and Wisconsin, with guidance and Program responsibility provided by the U.S. Army Corps of Engineers. The UMRS encompasses the commercially navigable reaches of the Upper Mississippi River, as well as the Illinois River and navigable portions of the Kaskaskia, Black, St. Croix, and Minnesota Rivers.

The mission of the LTRMP is to provide decision makers with information to maintain the Upper Mississippi River System as a sustainable large river ecosystem given its multiple-use character. The long-term goals of the Program are to understand the system, determine resource trends and impacts, develop management alternatives, manage information, and develop useful products.

This report was prepared under Strategy 2.2.4, *Monitor and Evaluate Aquatic and Terrestrial Vegetation*, Task 2.2.4.3, *Obtain and Evaluate Historical Information*, and Strategy 2.2.6, *Monitor and Evaluate Aquatic and Floodplain Habitat*, Task 2.2.6.3, *Obtain and Evaluate Historical Information*, Task 2.2.6.5, *Evaluate and Summarize a Change in Habitat*, as specified in Goal 2 of the Operating Plan of the LTRMP for the Upper Mississippi River System (USFWS 1992).

This report was developed with partial funding provided by the Long Term Resource Monitoring Program and is an adaptation of a report submitted by the author for the Scientific Assessment and Strategy Team's Ecology Background Report.

Additional copies of this report may be obtained from the National Technical Information Service, 5285 Port Royal Road, Springfield, Virginia 22161 (call toll free 1-800-553-6847).

This report should be cited as:

Yin, Y., and J. C. Nelson. 1995. Modifications to the Upper Mississippi River and Their Effects on Floodplain Forests. National Biological Service, Environmental Management Technical Center, Onalaska, Wisconsin, February 1995. LTRMP 95-T003. 17 pp.

BLANK PAGE

Contents

Page

Preface iii

Contents v

Tables vi

Figures vi

Abstract 1

Introduction 1

The Natural River 1

The Modified River 2

Presettlement Floodplain Forests 3

Present Floodplain Forests at the Open River Reach 4

Present Floodplain Forests at the Impounded River Reaches 5

Diminishing Floodplain Forests 5

Regeneration of Pioneer Forests 6

Future Approaches 6

References 7

Tables

Page

Table 1. Presettlement and present floodplain forest composition for portions of the open river reach and impounded reach of the Upper Mississippi River floodplain 9

Figures

Page

Figure 1. Cross-section diagrams of the Mississippi floodplain at river mile 46 of the open river reach 10

Figure 2. Cross-section diagrams of the Mississippi floodplain at river mile 218 of an impounded reach 11

Figure 3. Four common river categories in the Upper Mississippi River 12

Figure 4. Natural and modified hydrologic patterns and floodplain diagrams at river mile 46 of the open river reach of the Mississippi River 13

Figure 5. Natural and modified hydrologic patterns and floodplain diagrams at river mile 218 of an impounded river reach of the Mississippi River 14

Figure 6. Changes in land cover/land use, Pool 26, Upper Mississippi River, 1891-1989 15

Figure 7. Changes in land cover/land use, the open river reach, Upper Mississippi River, 1891-1989 16

Figure 8. Changes in forest age structure on the Missouri River floodplain 17

Modifications to the Upper Mississippi River and Their Effects on Floodplain Forests

By Yao Yin and John C. Nelson

Abstract

The natural Upper Mississippi River (UMR) and its tributaries flowed and meandered freely across large floodplain landscapes. Processes such as flooding, erosion, and sedimentation were powerful natural forces that shaped and maintained some floodplain forest communities. Beginning in the early nineteenth century, the UMR and its floodplain have been modified by navigation structures and agriculture. As a consequence of human modifications, a large portion of the UMR floodplain is no longer periodically inundated and the hydrologic patterns in the river, as well as on the floodplain, have changed. In general, agriculture and urban development have greatly reduced floodplain forest acres, especially in river reaches where a mainline levee system has been established. Compared to presettlement forest composition, our present floodplain forests are generally less diverse. Silver maple has dramatically increased in abundance and pioneer forests have probably been greatly reduced throughout much of the UMR floodplain.

Introduction

Large floodplain rivers are among the most highly productive ecosystems worldwide. Their high productivity is believed by many biologists to be closely related to periodic interactions between the aquatic river environment and the terrestrial floodplain environment (Junk et al. 1989; Brown 1985). Processes such as flooding, sedimentation, and erosion are powerful natural forces that shape and maintain the character of plant communities within large river-floodplain ecosystems. Species adaptations to water regimes still dictate plant assemblages despite human alterations to the system. For this reason, it is likely that hydrologic alterations are a key factor to understanding past and present floodplain forest characteristics.

It is no wonder that from the beginning of recorded human history civilizations prospered near large floodplain rivers. Before Euro-American settlement, many portions of the floodplain along the Upper Mississippi River (UMR) were comprised of prairie and forested wetlands (Finiels 1797). The presettlement bottomland forests were diverse in age structure and high in species richness because the Mississippi River and its tributaries meandered freely within the floodplain environment (Figs. 1A and 2A).

These floodplain communities and their abundant wildlife populations provided Native Americans with all the necessities of life. But to survive in the floodplain, these inhabitants had to be aware of and adapt to the often dramatic but predictable changes in river stage. Spring flooding could destroy villages, so Native Americans built far away from the river on the edge of the floodplain (Munson and Harn 1971). When river stages were low, such as in late summer, temporary camps were used along the river to gather fish, mussels, and other food.

Today, the UMR and its floodplain are much different than during the presettlement period. Navigation structures, levee systems, and stream channelization within the floodplain have had wide-ranging effects on the natural processes, particularly hydrology, that helped shape and maintain the character of the river-floodplain system (Figs. 1B and 2B).

Our intention in this document is to summarize some of the changes from presettlement to the present, with special emphasis on hydrology and floodplain forests. The discussion is based on information from Government Land Office (GLO) surveys conducted during the early part of the nineteenth century, as well as published literature, current field data, historical river stage data, and field observations by the authors.

The Natural River

Although major drainage patterns within the Upper Mississippi River Basin were established prior to the Pleistocene glaciation, the modern course of the Upper Mississippi River emerged following the Wisconsin epoch of glaciation approximately 10,000 years ago (Bray 1985; Hoop 1993). The Wisconsin period of glaciation consisted of a series of episodes and multiple ice sheets. As a result, the modern UMR corridor consists of a combination of floodplain, terraces, and river channels located between bluffs. Four river categories were identified by the Upper Mississippi River Basin Commission (UMRBC 1982): river valley bounded by bluffs, river bounded by floodplains, river bounded by terraces, and river with terraces located outside of a floodplain (Fig. 3). Terraces are high landform features that are rarely or no longer flooded and floodplains that are periodically inundated by overbank flows (Maddock 1976). Similar to other large alluvial rivers, the natural UMR not only interacted with its floodplain through periodical overbank floodwaters but also through changes in river and tributary positions. Older woodlands and marsh areas were eroded and old backwater lakes were filled in with sediments. New islands and marsh communities were formed and new backwater lakes created. The sometimes dramatic scenario of the natural river-floodplain landscape was captured in early explorer Henry Lewis's 1854 notes.

> . . . The islands do not originate in the middle of the river, but since its bed is constantly changing, the current hurls itself against the islands and drags them into the flood along with their trees and brush. The power of the current is so irresistible that we can cite an example in which an island of twenty-five acres was swept away in less than three weeks. Thousands of trees thrown into the stream in this way form snags and sawyers. From the Fall of St. Anthony to New Orleans there are more than three thousand islands that were formed thus . . .

While the above description illustrates the sometimes powerful nature of the flooding Mississippi and the dramatic changes that could occur to the landscape, the average spring flood of the time was much more subtle. Natural annual hydrologic patterns from the 1800s (Figs. 4A and 5A) exhibit moderate annual flooding. In the presettlement era, spring floodwaters gradually rose out of the river banks and flowed into the adjacent floodplain. While the entire floodplain was flooded during extreme events in some years, most often the flooding occurred in the lowest-lying floodplain habitats adjacent to the Mississippi and its tributaries. Later in the summer, the floodwaters retreated to well within the river banks. At times, the river became so shallow in some reaches that it was possible for a person to walk across. The forests along the river corridors consisted of many species, including cottonwood, pecan, willow, silver maple, sycamore, elm, sweetgum, and hackberry (Table 1).

In the spring, the Mississippi River normally overflowed and temporarily inundated the lowest-lying floodplain habitats. These habitats, termed aquatic terrestrial transition zones (ATTZs) (Junk et al. 1989), alternated between aquatic and terrestrial conditions. ATTZs were often comprised of diverse woodlands of various size structures and age classes and/or prairie wetlands. Plant species were well adapted to periodic flooding and during the spring aquatic phase provided river fishes with an abundant food supply, spawning and nursery habitats, and shelter from predators. In turn, the river deposited nutrient-rich sediments on the floodplain, which plants utilized throughout the summer growing season after spring floodwaters receded. Annual flooding in the autumn months could follow low flow periods during the summer growing season. The autumn flood was either a separate event or a prelude to spring flooding. During this time of year, plants began senescence and rising river water levels again flooded some ATTZs. It was in these transition zones that migrating waterfowl found an abundance of acorns and other food during their flight south.

The Modified River

Human impacts on the UMR were minimal before the nineteenth century. In the early nineteenth century, Euro-American settlement within the UMR valley increased steadily. During the 1830s, snags and other local obstructions such as shoals, sandbars, and rocks were removed from the mainstem Mississippi River to ensure a safer passage for steamboats (UMRBC 1982). In the second half of the nineteenth century, steamboat traffic increased sharply. In response to increasing navigation demands, the 1878 Congress authorized the U.S. Army Corps of Engineers to develop and maintain a 4.5-ft deep navigation channel between St. Paul, Minnesota, and St. Louis, Missouri. Wing dams were constructed perpendicular to river banks to divert river flows into the main channel. Side channels were cut off with closing dams and many riverbanks were stabilized by revetments.

In 1907, Congress authorized a deeper 6-ft channel project (UMRBC 1982). Subsequent river modifications included further river contraction and bank protection, as well as the construction of the first Lock and Dam at Keokuk, Iowa, in 1913.

In 1927, Congress authorized the development of a navigation channel 9-ft deep and 300-ft wide between the mouth of the Missouri River near St. Louis to the mouth of the Ohio River, near Cairo, Illinois. The 9-ft channel project resulted in much more extensive flow-constriction and bank stabilization structures. This portion of the UMR is approximately 201 miles long and is referred to as the "open river" because locks and dams are not used along this stretch of river to maintain the navigation channel.

In 1930, Congress authorized the extension of the 9-ft channel between St. Louis, Missouri, and St. Paul, Minnesota. During the 1930s, a series of 27 locks and dams was constructed. Each dam impounds water during low river flows to maintain a minimum 9-ft deep navigation channel. This portion of the UMR is approximately 652 miles long and is referred to as the "impounded river."

Prior to or concurrent with navigation projects, private and Federal levee systems were built to manage floodwater. At the open river reach, construction of State and Federal levees started after 1881 (Chen and Simons 1986; Johnson et al. 1974), but was not intensive until after 1907 (Simons et al. 1974). Dikes and revetments lock the position of the river and levees prevent overbank flow from spreading. By restricting channel meandering and increasing flood intensities, humans have altered the conditions to which the natural forest species were adapted (Fig. 4B). This has resulted in forests of less diversity because willow and silver maple have replaced most of the other species present in the early 1800s.

The flood regime has been altered due to dam operations that maintain target water levels throughout the year (Fig. 5B). This water level management strategy eliminates the period of low flow that was part of the natural river's hydrologic pattern. Thus, forests species now bordering the river in impounded reaches must be well adapted to high soil moisture content throughout the growing season. Silver maple is well adapted to the modified conditions and has therefore become the most abundant species on the floodplain. It is quite possible that our future forests may be entirely dominated by silver maple because this species is best adapted to modified conditions, especially high soil moisture and increased flood disturbance.

Although the entire modern-day UMR is highly restricted and regulated, events like the flood of 1993 are constant reminders of one very important characteristic of large floodplain rivers; the river and its floodplain are closely linked due to processes beyond human control.

Presettlement Floodplain Forests

Before Euro-American settlement, the floodplain of the UMR included vast swamplands, prairies, marshes, and forests (Finiels 1797; Turner 1934; Nelson et al. 1994). At the southernmost portion of the UMR near Cape Girardeau, Missouri, the presettlement floodplain landscape was dominated by forests (Fig. 1A). In 1809, General Land Office (GLO) surveyors recorded 19 tree taxa along the Mississippi riverbanks as witness trees. Cottonwood (*Populus deltoides* Marshall) and sycamore (*Platanus occidentalis* L.) were the two most dominant species of these taxa. Farther away from the river in that portion of the floodplain which today is shielded by the mainline levee, GLO surveyors recorded a total of 31 tree taxa (Table 1). Of these taxa, elm (*Ulmus rubra* Muhl, *U.* spp.), hackberry (*Celtis occidentalis* L.), sweetgum (*Liquidambar styraciflua* L.), and ash (*Fraxinus pennsylvanica* Marshall, *F.* spp.) were the most dominant species. Close associates included hickories (*Carya* spp.), white oak (*Quercus alba* L.), American beech (*Fagus grandifolia* Ehrh), and yellow poplar (*Liriodendron tulipifera* L.).

North of the open river near St. Louis, prairies dominated the presettlement floodplain landscape. Forests were restricted to areas along the riverbanks, tributary streams, and isolated groves surrounded by floodplain prairies. GLO surveys at the confluence of the Illinois and Mississippi Rivers in 1817 recorded 18 taxa of witness trees (Table 1). These forests were dominated by hackberry, pecan (*Carya illinoinensis* [Wangenl] K. Koch), elm, willow (*Salix* spp.), and close associates, including silver maple (*Acer saccharinum* L.), pin oak (*Quercus palustris* Muenchh), and ash.

The GLO surveyors of both these study areas described some of the conditions they encountered on the floodplain. In the open river reach near Cape Girardeau, Missouri, surveyors encountered numerous cypress swamps. In 1809, the swamps varied greatly in size, with high water making the largest areas inaccessible. In 1850, another survey was attempted in the Horseshoe Lake area. After measuring one section line, the deputy surveyor noted problems related to flooding.

> The line cannot be surveyed at this time, in consequence of the overflow occurred by the Ohio-river backing up the Cache-river (*sic*), which has inundated the country in many places along the section line, to a depth of three to five feet . . .

(GLO survey notes, IL, pg. 83, vol. 491B). Near St. Louis, a deputy surveyor noted at the Mississippi Riverbank

> . . . level rich bottom and subject to inundation of from 2 to 10 ft deep as appears by the water marks on the trees. Timber cottonwood, sycamore, elm, red bud, and pin oaks, undergrowth vines and bushes of various sorts . . .

After measuring 57 chains (~1150 m) away from the riverbank, he also noted

> . . . Top of bank 10 ft high (on) south side of a lake where (we) enter prairie. The prairie is good rich soil and fit for cultivation . . .

(GLO surveyors notes, Missouri, page 40, private survey volume 3). Trees of very large size were not uncommon in the GLO notes; cottonwoods were recorded as 5 and 9 ft in diameter.

According to GLO survey records, presettlement floodplain forests farther north in southeastern Minnesota (Houston County) and northeastern Iowa (Allamakee and Clayton Counties) were dominated by ash (*Fraxinus* spp.) and silver maple (Moore 1988). A total of 26 taxa was recorded among 950 trees in the GLO records. Other components recorded were hickory species (*Carya* spp.), two walnut species (*Juglans cinerea*, *J. nigra*), and five oak species (*Quercus alba*, *Q. bicolor* Willd, *Q. macrocarpa* Michx, *Q. velutina* Lam, *Q.* spp.).

Present Floodplain Forests at the Open River Reach

Federal levees and navigation structures have changed the character of the Mississippi River and its hydrologic regime at the open river reach. Because floodwaters are restricted to a much narrower area between levees, intensity and duration of flooding are aggregated (U.S. Army Corps of Engineers data, Fig. 1B; Belt 1975). Elevated floodwaters are now more likely to overtop tree root crowns and remain this high for an extended period of time. As a result, tree growth may be adversely affected and some less flood-tolerant tree species may disappear (Johnson et al. 1974). Within levee districts where flooding can no longer occur, the impact of levees on the forests is the opposite. In these districts, moisture and nutrients are no longer replenished by periodic overbank flows. Also, because the bed of the main channel has been lowered as much as 11 ft (Johnson et al. 1974), less moisture may be available from the underground water table.

A 1993 survey (Table 1) at the open river reach near Cape Girardeau, Missouri, indicates that changes in forest composition and structure since presettlement are related to changes in hydrology resulting from navigation structures and the Federal levees. The number of species encountered has decreased on both sides of the levees. Adjacent to the Mississippi River and between levees, species such as oak (*Quercus* spp.), American beech, walnut (*Juglans* spp.), pecan, and hickory have disappeared and the abundance of cottonwood and sycamore, two pioneer species that require newly formed and somewhat sandy substrates for regeneration, have also decreased significantly.

Willow and silver maple have replaced cottonwood and sycamore as the dominant species. Sediments which rapidly accumulate in the fields between wing dams have narrowed the river channel. These newly formed sites usually are quickly invaded by willow, which is soon replaced by the more shade-tolerant silver maple. Outside the mainline levee and within the levee districts, tree species typical of pioneer and transitional forests such as cottonwood, sycamore, elm, and hackberry have decreased since presettlement. Pin oak has become the most dominant species because the floodplain has been drained for agriculture (Table 1) and flooding has been eliminated; pin oak possibly prefers the resulting drier site conditions.

Present Floodplain Forests at the Impounded River Reaches

The effects of navigation dams have significantly changed natural hydrologic patterns within the impounded reaches of the UMR (Grubaugh and Anderson 1988). However, the degree of change varies with proximity to a navigation dam. Annual water level patterns of the river immediately below each dam are most similar to the natural or pre-dam hydrologic pattern as displayed in Fig. 2A. During high flows, the rapid current, reduced in sediment load, scours the channel. During low flows, water levels drop to well within the riverbanks, and the water table in the floodplain is similarly lowered. Immediately above each dam, water level patterns are most dissimilar to natural or predam patterns. At these sites, water levels are most severely raised and most stable throughout the growing season (Fig. 2B). Floodplain forests immediately upstream from navigation dams are probably subjected to high soil saturation throughout much of the year due to elevated water tables.

Yeager (1949) documented the effects of river impoundment on floodplain forests following the completion of Lock and Dam 26 at Alton, Illinois, in 1938. After 6 years, trees on the lowest permanently inundated floodplains were nearly completely eliminated. Only the most flood-tolerant species remained in areas where the groundwater table was raised to near-surface level. On higher floodplain elevations less affected by inundation, trees showed better survival but less flood-tolerant species like pin oak suffered heavy mortality.

A comparison of presettlement and present forests within a portion of Pool 26 revealed significant changes in composition and structure (Nelson et al. 1994). The presettlement forest was dominated by several species including hackberry, pecan, elm, willow, and cottonwood, whereas the present floodplain forest is dominated by one species, the silver maple (Table 1). Sediments are rapidly accumulating in the artificial backwaters, which is creating new mud flats usually invaded by willow and soon overtaken by the more shade-tolerant silver maple. Similar results were revealed (Moore 1988) in southeast Minnesota and northern Iowa, where silver maple replaced ash as the single dominant species in the present floodplain forests, while oak and hickory species were reduced.

Diminishing Floodplain Forests

Agriculture and urban development have been two major causes for rapidly diminishing forests throughout most of the UMR floodplain. According to data presented in Peck and Smart (1986), by 1929 farmland and urban areas had expanded to ~22% of the total area in the UMR floodplain, while forests were reduced to ~29% of the total area. Construction of navigation dams increased the water surface area of the Mississippi River and eliminated forests from permanently inundated areas (Green 1947; Yeager 1949). However, the net loss of forests between 1929 and 1973 was slight at ~2% of the total area (Peck and Smart 1986). A recent study revealed that by 1989, forests occupied only ~14% of the total area from bluff to bluff in the UMR floodplain (Laustrup and Lowenberg 1994). The percentage of forested areas is highest in Navigation Pools 2 to 13 (18.2%), intermediate in Pools 14 to 27 (13.6%), and lowest in the open river reach (12.4%). Two sets of geographic information system (GIS) maps are provided to illustrate changes in forest acreage, along with changes in other land cover/land use types between 1891 and 1989. One set of the GIS maps displays an impounded reach at Pool 26, Alton, Illinois (Fig. 6). This map does not cover the entire floodplain, but the trend of change is well represented. Field notes of GLO office surveyors from 1817 and plat maps based on the same GLO surveys indicate that the Pool 26 floodplain was ~63% prairie wetlands with forests bordering the riverbank and tributary streams.

Agriculture had nearly eliminated the prairies by 1891, while forests were less affected. The second set of GIS maps are from the open river near Cape Girardeau, Missouri (Fig. 7). GLO surveyor field notes from 1809 and related plat maps indicate that the floodplain at this location was completely forested prior to settlement. Agriculture had eliminated much of the forests by 1891, and by 1989 agriculture had become the predominant land cover type. The remaining forests are primarily limited to areas immediately adjacent to the river channel and to state preserves, conservation areas, and private hunting clubs.

Regeneration of Pioneer Forests

Little information is available on qualitative changes of forests in the UMR. Some assessments have to be made based on studies of other large river systems. According to these studies, flooding and lateral movement of the river create and maintain a constant influx of new alluvial soils, which are quickly colonized by early pioneer forests (dominant species may include willow and cottonwood) and then develop into old pioneer forests (dominant species may include cottonwood, sycamore, willow, and others). As old pioneer forests develop into transitional forests (dominant species may include silver maple, boxelder [*Acer negundo* L.], hackberry, elm, ash, and others), they will be eroded away by the river and then develop into early pioneer forests again. Only a small portion of the forest reaches late-successional or climax stages. Survival of early pioneer forests is comparable to a reversed "J" curve (Everitt 1968; Johnson 1992). That is, the acreage of stands decreases with the increase of stand age, resulting in more pioneer forests and less climax (oak-hickory) forests.

On the Missouri River, the influx of new alluvial soils has been greatly reduced since the construction of large reservoir dams. Between the Oahe Reservoir and the Garrison Dam, the erosion rate has decreased from 133 ha/yr in the late 1800s (pre-dam) to a present rate of 21 ha/yr (post-dam), while deposition decreased from 165 ha/yr to 1.3 ha/yr between the same two periods (Johnson 1992). Because of the reduced formation of new alluvial soils required for cottonwood-willow regeneration, the present forests of the Missouri River System are comprised of less pioneer forests and more transitional forests (Fig. 8) (Johnson 1992).

Based on the likely changes predicted by both Johnson and others (1974) and Simons and others (1974), the acreage of floodplain forests in the open river reach of the UMR is expected to increase in the near future. Fields between wing dams and side channels have been rapidly filling with sediments. All natural side channels may disappear, even in the absence of further human-induced changes in river hydrology or geomorphology. While some of the newly deposited areas will become farmland, others will likely be colonized with forests. We predict that changes occurring in the Missouri River will similarly occur within the open river reach of the UMR. While existing cottonwood-willow-sycamore stands are changing toward transitional silver maple-boxelder forests, few new stands of cottonwood-willow-sycamore will be created through natural regeneration. The end result will be a probable drastic reduction of pioneer cottonwood-willow-sycamore stands, while the total acres of forests may increase slightly.

The fate of pioneer forests in the impounded reaches of the UMR is less clear because the impounded reaches, with their levees, wing dams, and revetments have less extensive lateral restrictions than the open river reaches. In the next 50-150 years, sediment deposition in backwater areas will continue to form new alluvial soils. Afterward, a new but unknown balance of erosion and deposition may be established. However, field observations indicate that willow and silver maple are the major regenerating species in newly deposited alluvial soils, while cottonwood and sycamore are regenerating poorly. This may be the result of incompatibility between the processes of cottonwood and sycamore regeneration and the modification of the natural hydrologic regime. Similar mechanisms were revealed in the Milk River in southern Alberta and northern Montana (Bradley and Smith 1986).

Future Approaches

It is a great challenge to river biologists and managers to sustain multiple uses and at the same time protect the ecological integrity of the UMR. From the forest manager's viewpoint, preserving and restoring forests on the UMR floodplain will require a continuous effort. As a part of this effort, it is important to study presettlement floodplain ecosystems as well as the qualitative changes of the existing forests, such as natural regeneration, diversity, and productivity. Future research efforts need to quantify the relationships between hydrologic regimes (including flood timing, frequency, intensity, and duration), natural regeneration, and growth of woody species. Experimentation and on-site documentation of the reaction of trees to water table and water-table fluctuations remain an open field for investigation (Bedinger 1978). Forest simulation models may be developed to synthesize field data and to predict the effects of different river regulation schemes on forests (Bedinger 1978). In the meantime, restoring forest diversity through ecologically sound methods of regulating river flow, coupled with artificial regeneration of some species, should be set as the short-term management goal.

References

Bedinger, M. S. 1978. Relation between forest species and flooding. American Water Resources Association. November:427-435.

Belt, C. B., Jr. 1975. The 1973 flood and man's constriction of the Mississippi River. Science 189:681-684.

Bradley, C. E., and D. G. Smith. 1986. Plains cottonwood recruitment and survival on a prairie meandering river floodplain, Milk River, southern Alberta and northern Montana. Canadian Journal of Botany 64:1433-1442.

Bray, E. C. 1985. Ancient rivers, modern valleys: What the glaciers did. The Science Museum of Minnesota, St. Paul. 32 pp.

Brown, S. 1985. Response of tree growth to changes in flooding regime in a mixed hardwood bottomland forest in southern Illinois. Pages 203-208 *in* Dawson, J. O. and K. A. Majerus, editors. Proceedings of the Fifth Central Hardwood Forest Conference. Department of Forestry and Agriculture Experiment Station, University of Illinois, Urbana-Champaign, and Society of American Foresters.

Chen, Y. H., and D. B. Simons. 1986. Hydrology, hydraulics, and geomorphology of the Upper Mississippi River System. Pages 5-19 *in* M. M. Smart, editor. Ecological Perspectives of the Upper Mississippi River. Dr. W. Junk Publishers, Boston.

Everitt, B. L. 1968. Use of the cottonwood in a investigation of the recent history of a flood plain. American Journal of Science 266:417-439.

Finiels, Nicholas de. 1797. An account of Upper Louisiana. Carl J. Ekberg and William E. Foley, editors. University of Missouri Press, Columbia. 153 pp.

Grubaugh, J. W. and R. V. Anderson. 1988. Spatial and temporal availability of floodplain habitat: Long term changes at Pool 19, Mississippi River. American Midland Naturalist 119(2):402-410.

Green, W. E. 1947. Effects of water impoundment on tree mortality and growth. Journal of Forestry 45:11-120.

Hoop, R. 1993. A river of grain: The evolution of commercial navigation on the Upper Mississippi River. University of Wisconsin-Madison College of Agricultural and Life Sciences Research Report (R3584). 125 pp.

Johnson, J. H., R. C. Solomon, C. R. Bingham, B. K. Colbert, W. P. Emge, D. B. Mathis, R. W. Hall, Jr. 1974. Environmental analysis and assessment of the Mississippi River 9-ft channel project between St. Louis, Missouri, and Cairo, Illinois. Technical Report Y-74-1 of U.S. Army Corps of Engineers St. Louis District. Prepared by Environmental Effects Laboratory, U.S. Army Corps of Engineers Waterways Experiment Station, Vicksburg, Mississippi.

Johnson, W. C. 1992. Dams and riparian forests: Case study from the upper Missouri River. Rivers 3:229-242.

Junk, W. J., P. B. Bayley, and R. E. Sparks. 1989. The flood pulse concept in river-floodplain systems. Pages 110-127 *in* D. P. Dodge, editor. Proceedings of the International Large River Symposium. Canadian Special Publication of Fish and Aquatic Science 106.

Laustrup, M. S. and C. D. Lowenberg. 1994. Development of a systemic land cover/land use database for the Upper Mississippi River System derived from Landsat Thematic Mapper satellite data. National Biological Survey, Environmental Management Technical Center, Onalaska, Wisconsin, May 1994. LTRMP 94-T001. 103 pp. (NTIS #PB94-186889)

Lewis, H. 1854. *Das illustrirte Mississippithal*. Translated by A. Hermina Poatgieter and edited by Bertha L. Heilbron. The valley of the Mississippi illustrated. Minnesota Historical Society Press, St. Paul. 1967.

Maddock, T., Jr. 1976. A primer on floodplain dynamics. Journal of Soil and Water Conservation: March/April.

Moore, G. F. 1988. Plant communities of Effigy Mounds National Monument and their relationship to presettlement regional vegetation. Master degree thesis. Department of Landscape Architecture, University of Wisconsin, Madison. 148 pp.

Munson, P. J., and A. D. Harn. 1971. Archaeological surveys of the American bottoms and adjacent bluffs, Illinois. Illinois State Museum Reports of Investigations, No. 21. 123 pp.

Nelson, J. C., A. Redmond, and R. E. Sparks. 1994. Impacts of settlement on floodplain vegetation at the confluence of the Illinois and Mississippi Rivers. Transactions of the Illinois State Academy of Science 87(3&4):117-133

Peck, J. H. and M. M. Smart. 1986. An assessment of the aquatic and wetland vegetation of the Upper Mississippi River. Pages 57-75 *in* M. M. Smart, editor. Ecological Perspectives of Upper Mississippi River. Dr. W. Junk Publishers, Boston.

Simons, D. B., S. A. Schumm, and M. A. Stevens. 1974. Geomorphology of the Middle Mississippi River. Report for U.S. Army Corps of Engineers Waterways Experiment Station, Vicksburg, Mississippi. Prepared by U.S. Army Corps of Engineers St. Louis District under Contract No. DACW39-73-C-0026. 123 pp.

Turner, L. M. 1934. Grasslands in the floodplain of Illinois rivers. American Middleland Naturalists 15:770-780.

Upper Mississippi River Basin Commission (UMRBC). 1982. Comprehensive master plan for the management of the Upper Mississippi River System. Upper Mississippi River Basin Commission, Minneapolis, Minnesota. 193 pp.

U.S. Fish and Wildlife Service (USFWS). 1992. Operating Plan for the Upper Mississippi River System Long Term Resource Monitoring Program. Environmental Management Technical Center, Onalaska, Wisconsin. Revised September 1993. EMTC 91-P002. 179 pp. (NTIS #PB94-160199)

Yeager, L. E. 1949. Effect of permanent flooding in a river timber area. Bulletin of Illinois Natural Survey 25:33-65.

Table 1. **Presettlement and present floodplain forest composition for portions of the open river reach and impounded reach of the Upper Mississippi River floodplain. Importance value and change in importance value of all stems 10.0 cm or greater diameter at breast height in the presettlement is compared to the present.**

Genus/species	Open River/Protected Importance Value			Open River/Unprotected Importance Value			Impounded River/Pool 26 Importance Value		
Common name	1809	1993	▲	1809	1993	▲	1817	1992	▲
Ulmus spp.	28.5	14.8	-13.7	15.4	7.5	-7.9	22.1	8.7	-13.4
Celtis spp.	25.4	8.6	-16.8	9.4	3.2	-6.2	30.4	19.7	-10.7
Liquidambar styraciflua L.	23.5	23.3	-0.2	9.6	0.5	-9.1	----	----	----
Fraxinus spp.	21.6	21.5	-0.1	3.7	1.6	-2.1	11.0	17.9	+6.9
Carya spp.	10.9	4.3	-6.6	4.6	----	-4.6	----	----	----
Quercus alba L.	10.8	12.7	+1.9	----	----	----	3.1	----	-3.1
Fagus grandifolia Ehrh.	10.4	----	-10.4	3.5	----	-3.5	----	----	----
Liriodendron tulipifera L.	9.4	----	-9.4	----	----	----	----	----	----
Platanus occidentalis L.	7.4	4.3	-3.1	51.2	11.8	-39.4	2.8	1.9	-0.9
Acer saccharinum L.	6.5	3.4	-3.1	----	39.7	+39.7	16.1	86.3	+70.2
Quercus velutina Lam.	5.9	----	-5.9	----	----	----	7.7	----	-7.7
Acer negundo L.	5.8	6.3	+0.5	8.3	28.2	+19.9	5.8	14.7	+8.9
Taxodium distichum (L.) Rich.	3.9	14.6	+10.7	----	----	----	----	----	----
Fraxinus profunda (Bush) Bush.	3.9	----	-3.9	0.9	----	-0.9	----	----	----
Populus deltoides Marshall.	3.4	----	-3.4	80.2	36.1	-44.1	20.4	13.1	-7.3
Acer saccharum Marshall.	3.2	----	-3.2	----	----	----	----	----	----
Morus rubra L.	2.0	----	-2.0	4.1	3.2	-0.9	3.5	0.4	-3.1
Sassafras albidum (Nutt.) Nees.	2.0	----	-2.0	1.6	----	-1.6	----	----	----
Juglans spp.	1.5	1.1	-0.4	0.6	----	-0.6	----	0.2	+0.2
Quercus lyrata Walter.	1.3	----	-1.3	1.2	----	-1.2	----	----	----
Gleditsia triacanthos L.	1.3	1.3	0.0	----	----	----	5.2	0.3	-4.9
Quercus nigra L.	1.2	----	-1.2	----	----	----	----	----	----
Quercus palustris Muenchh.	1.1	30.6	+29.5	----	----	----	11.5	9.5	-2.0
Tilia americana L.	1.1	----	-1.1	----	----	----	----	----	----
Gymnocladus dioicus Lam.	1.0	----	-1.0	----	----	----	----	----	----
Salix spp.	1.0	9.0	+8.0	3.3	60.3	+57.0	20.7	12.9	-7.8
Asimina triloba (L.) Dunal.	0.9	----	-0.9	----	----	----	1.5	----	-1.5
Quercus rubra L.	0.7	----	-0.7	----	----	----	----	----	----
Nyssa spp.	0.5	5.4	+4.9	----	----	----	----	----	----
Querus falcata Michx.	0.3	13.8	+13.5	----	----	----	----	----	----
Cercis canadensis L.	0.1	----	-0.1	1.2	----	-1.2	3.1	----	-3.1
Acer rubrum L.	----	8.8	+8.8	----	7.1	+7.1	----	----	----
Crataegus spp.	----	1.0	+1.0	----	----	----	1.8	1.1	-0.7
Diospyros virginiana L.	----	4.4	+4.4	----	----	----	----	1.9	+1.9
Gleditsia aquatica Marshall.	----	5.8	+5.8	----	----	----	----	----	----
Quercus macrocarpa Michx.	----	3.2	+3.2	----	----	----	1.7	1.1	-0.6
Aesculus glabra Willd.	----	----	----	0.7	----	-0.7	----	----	----
Carya illinoensis (Wangenh.) K. Koch.	----	----	----	----	----	----	30.0	9.1	-20.9
Ilex decidua Walter.	----	----	----	0.3	----	-0.3	----	----	----
Prunus serotina Ehrh.	----	----	----	0.3	----	-0.3	----	----	----
Totals	196.5	198.2	1.6	199.5	199.8	0.3	197.0	198.0	0.0

Sample size: Open River/Protected 1809 n = 188 stems, 1993 n = 319 stems; Open River/Protected 1809 n = 745 stems, 1993 n = 118 stems; Impounded River/Pool 26 1817 n = 96 stems, 1992 n = 628 stems, ▲ = change

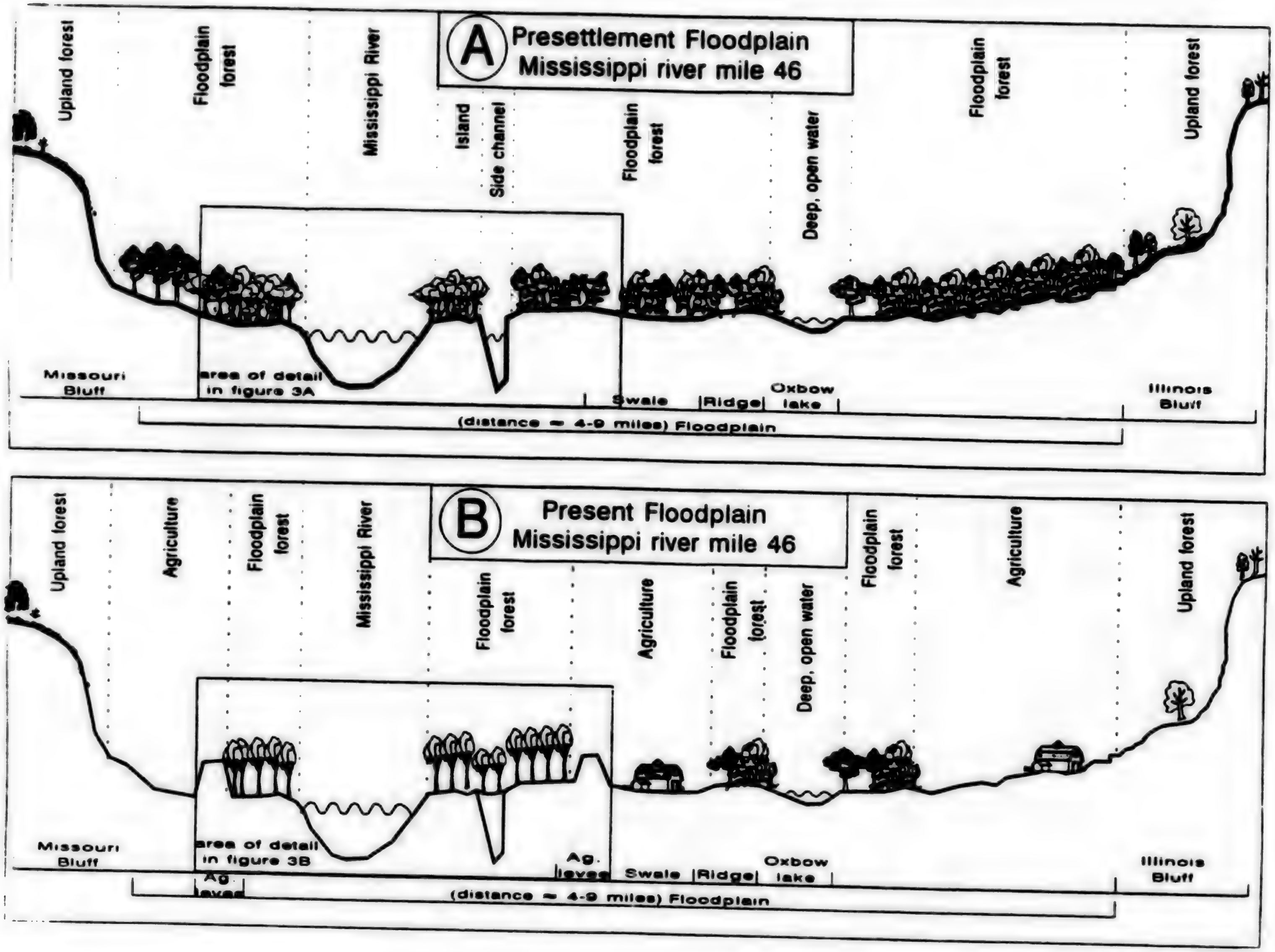


Figure 1. Cross-section diagrams of the Mississippi floodplain at river mile 46 of the open river reach. In the presettlement era (Part A), the floodplain was covered with bottomland hardwood forests. Presently (Part B), levees and dikes restrict river meandering and most of the bottomland hardwood forests have been cleared for agriculture.

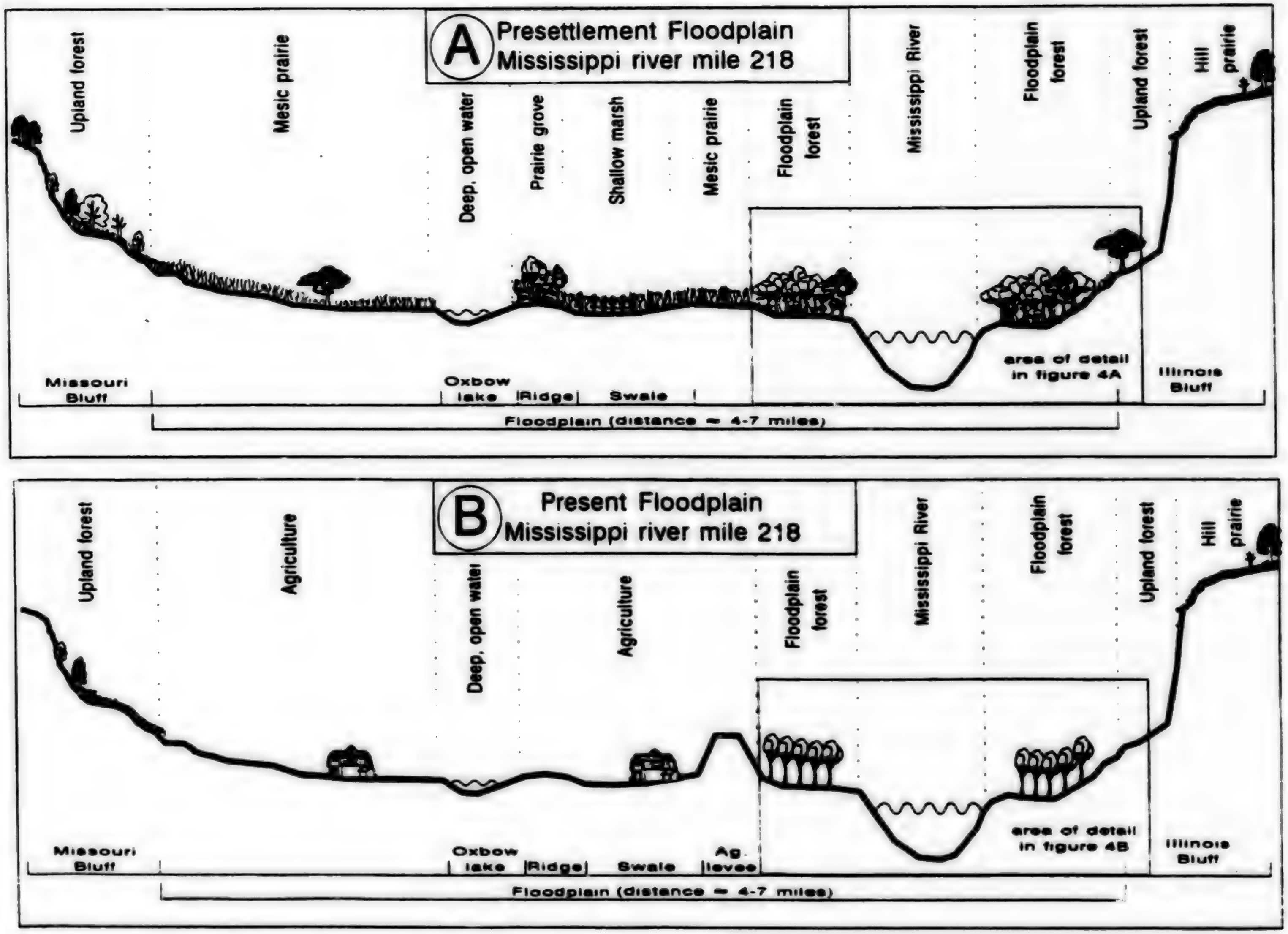


Figure 2. Cross-section diagrams of the Mississippi floodplain at river mile 218 of an impounded reach. In the presettlement period (Part A), the floodplain was dominated by prairie wetlands. Presently (Part B), agriculture has replaced the prairies but many of the floodplain forests still remain, although less diverse in structure and species diversity.

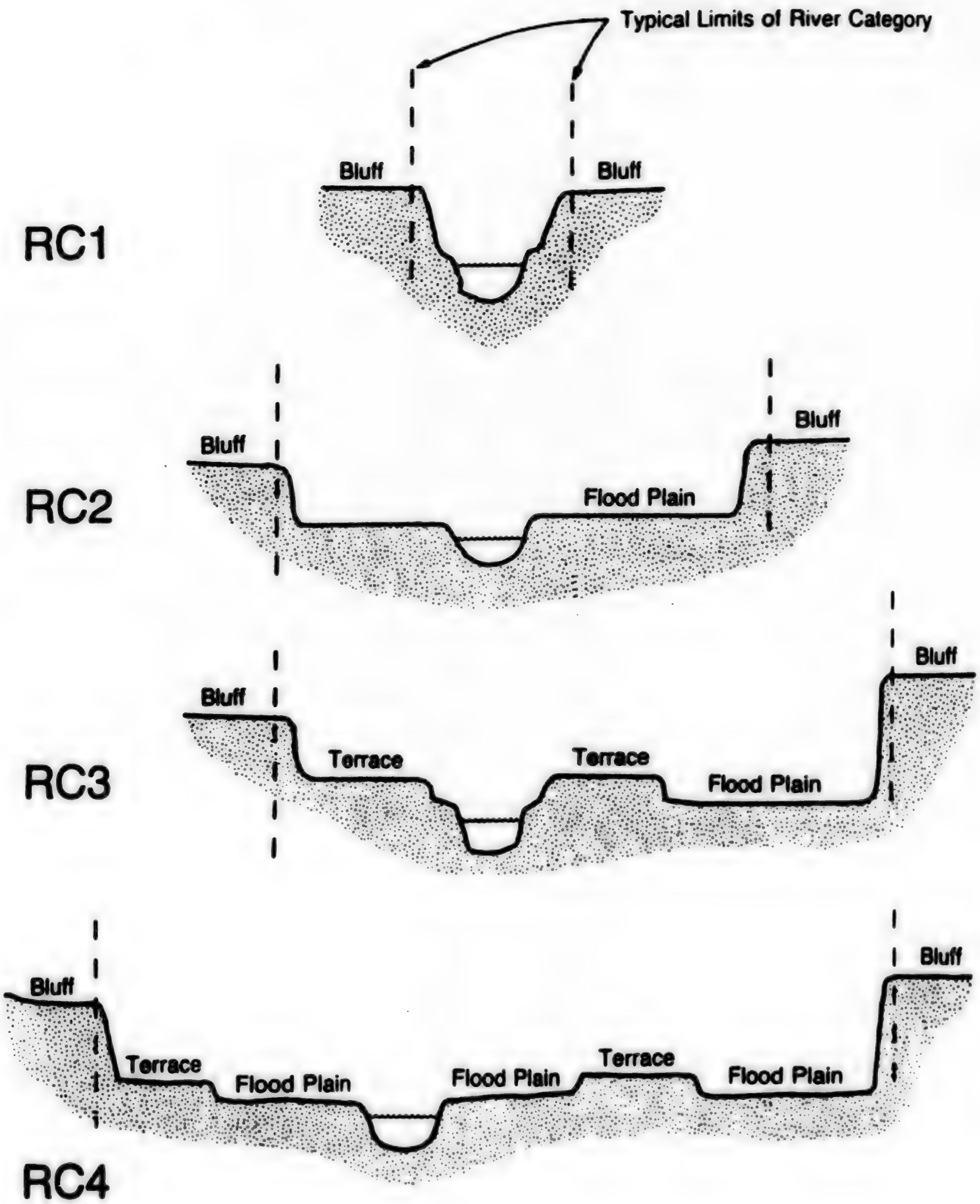


Figure 3. Four common river categories in the Upper Mississippi River. Source: Upper Mississippi River Basin Commission 1982.

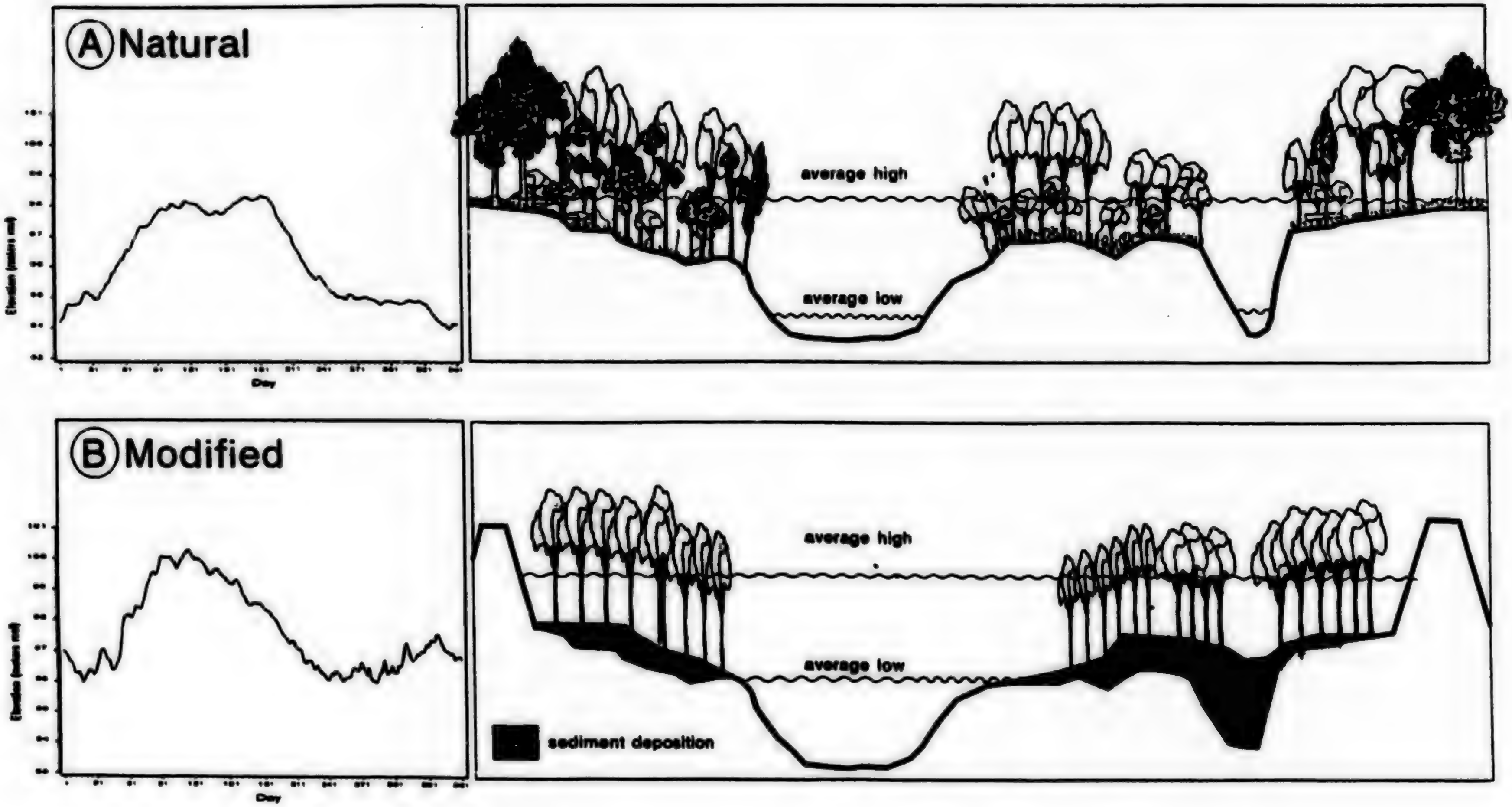


Figure 4. Natural and modified hydrologic patterns and floodplain diagrams at river mile 46 of the open river reach of the Mississippi River. Prior to settlement, the natural river (Part A) exhibited moderate annual flooding. Presently (Part B), both annual high and annual low flows are elevated.

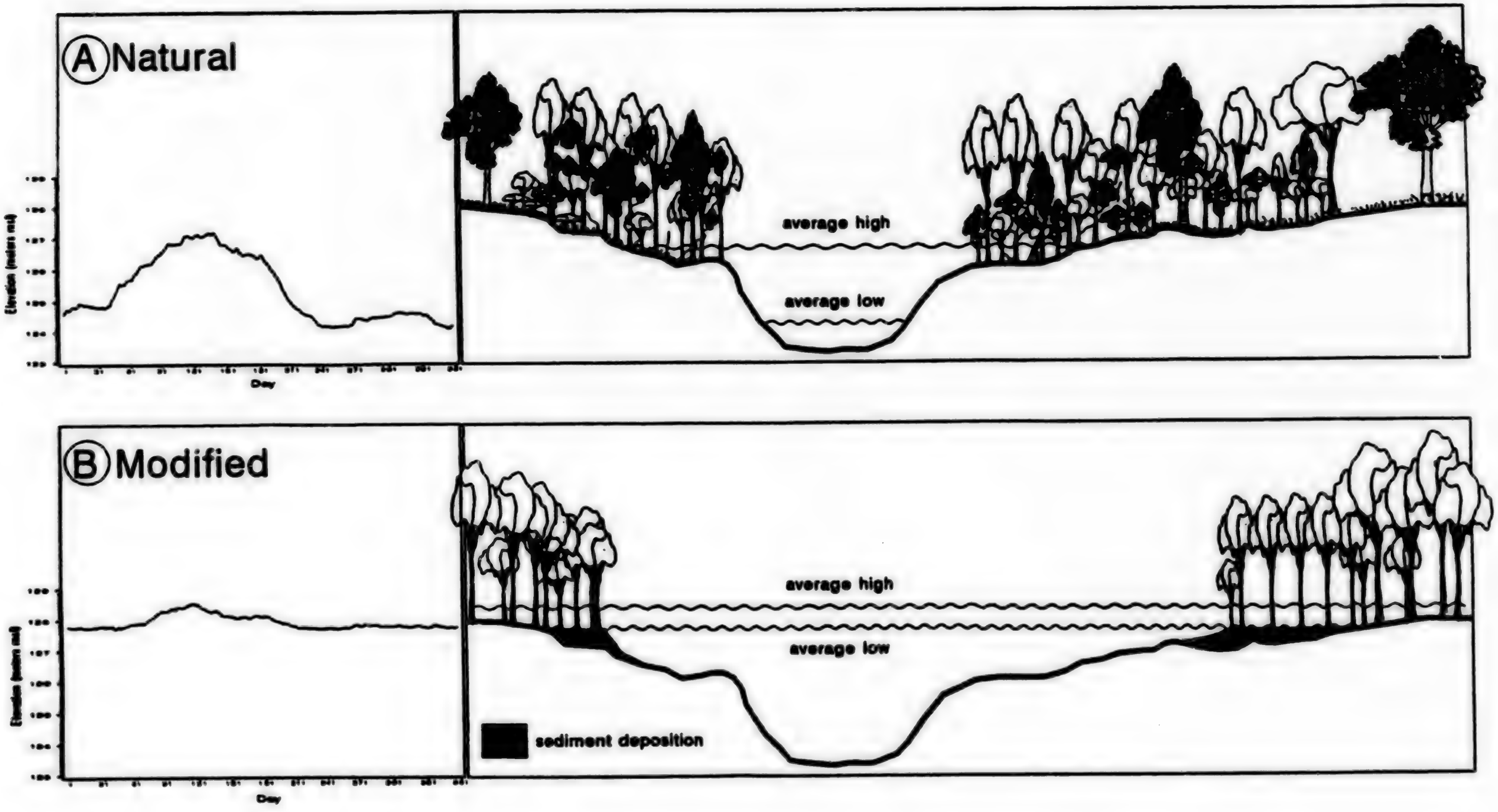
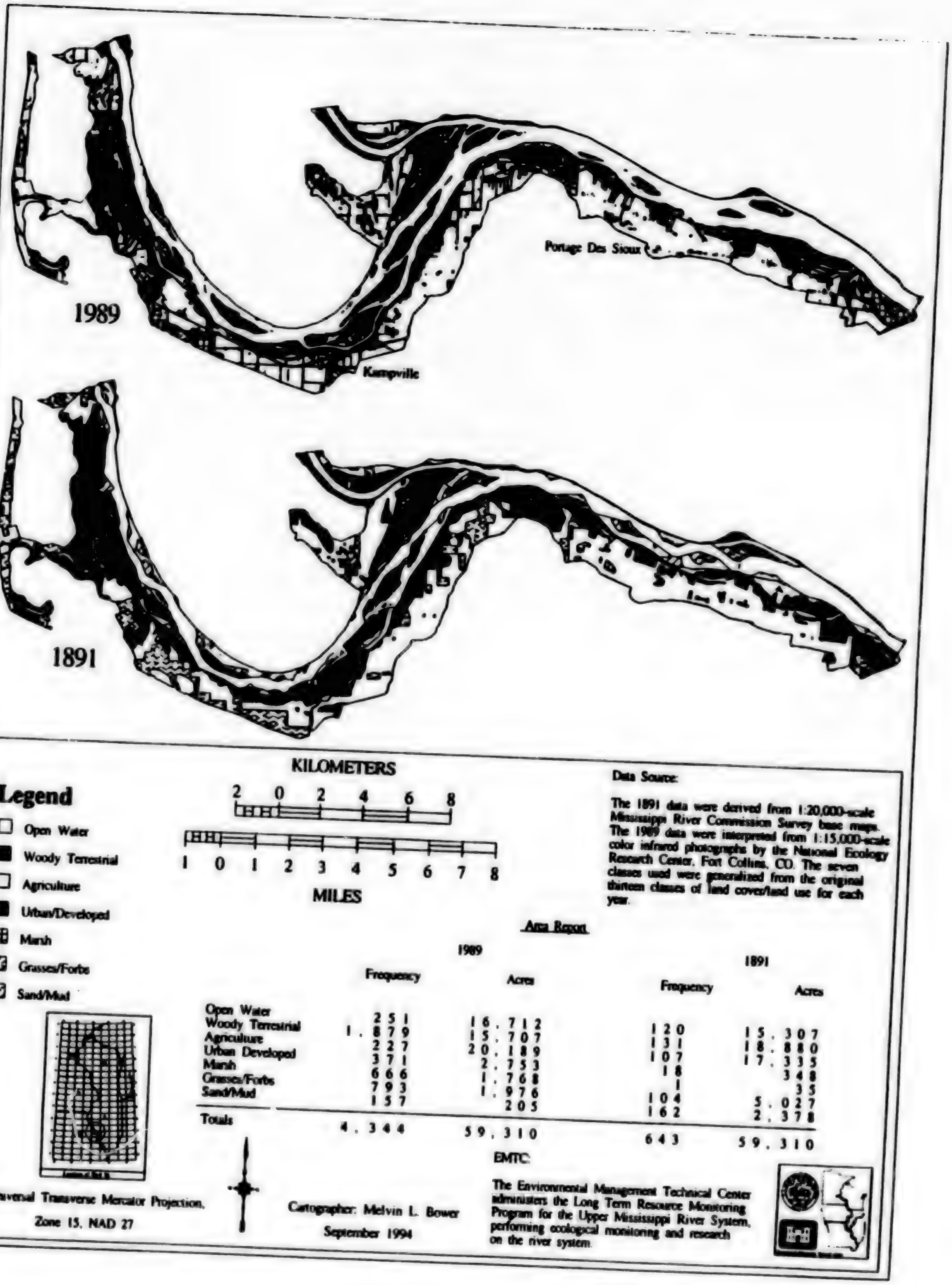


Figure 5. Natural and modified hydrologic patterns and floodplain diagrams at river mile 218 of an impounded river reach of the Mississippi River. During presettlement (Part A), the natural river exhibited moderate spring floods followed in the autumn by a second flood of even lesser magnitude. Presently (Part B), the flood regime has been altered by dam operations that maintain target water levels throughout the year.



Data Source:

The 1891 data were derived from 1:20,000-scale Mississippi River Commission Survey base maps. The 1989 data were interpreted from 1:15,000-scale color infrared photographs by the National Ecology Research Center, Fort Collins, CO. The seven classes used were generalized from the original thirteen classes of land cover/land use for each year.

Area Report

	1989		1891	
	Frequency	Acres	Frequency	Acres
Open Water	251	16,712	120	15,307
Woody Terrestrial	1,879	15,707	131	18,880
Agriculture	227	20,189	107	17,335
Urban Developed	371	2,753	18	348
Marsh	666	1,768	1	35
Grasses/Forbs	793	1,976	104	5,027
Sand/Mud	157	205	162	2,378
Totals	4,344	59,310	643	59,310

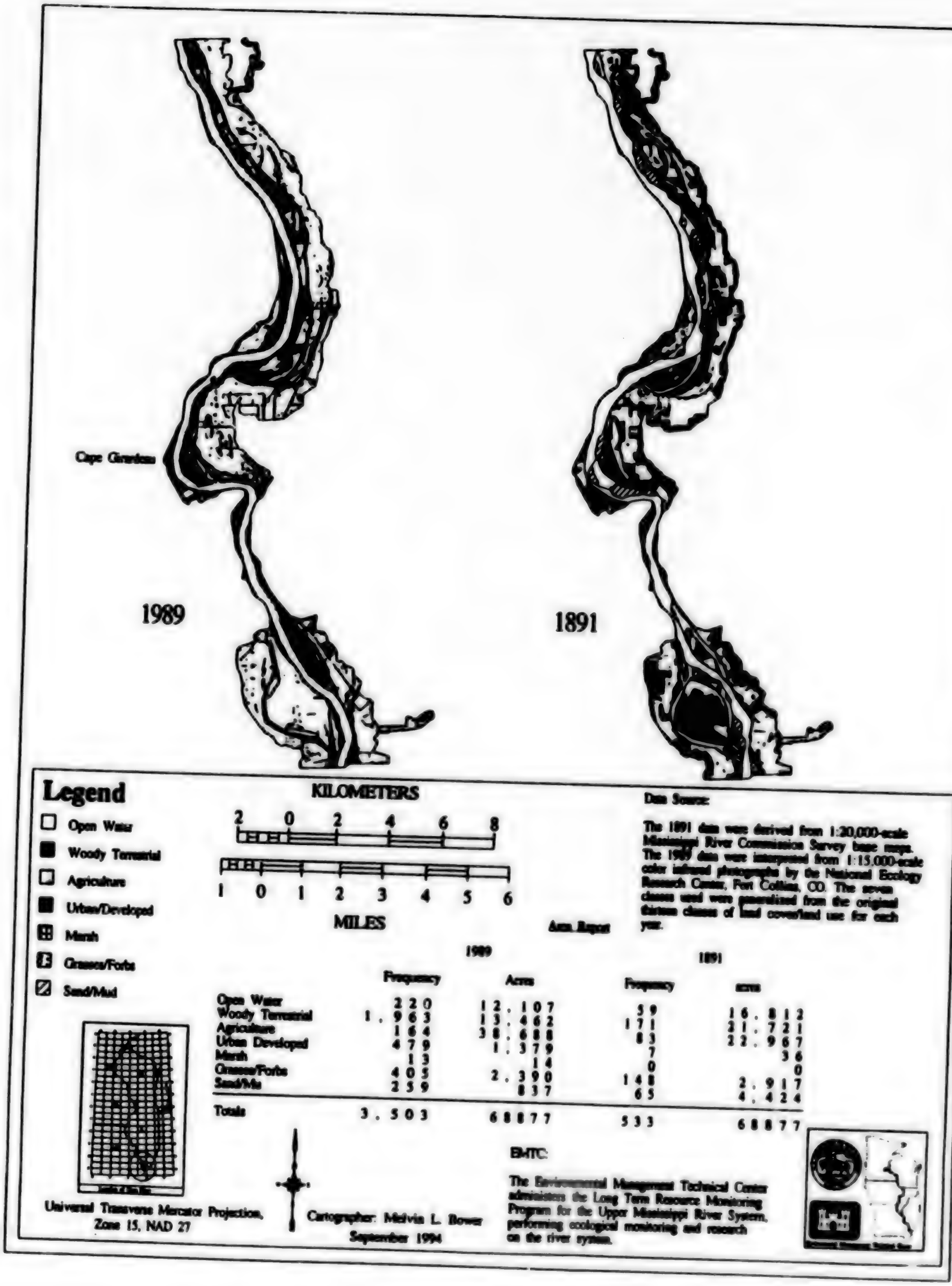
EMTC:

The Environmental Management Technical Center administers the Long Term Resource Monitoring Program for the Upper Mississippi River System, performing ecological monitoring and research on the river system.

Universal Transverse Mercator Projection, Zone 15, NAD 27

Cartographer: Melvin L. Bower
September 1994

Figure 6. Changes in land cover/land use, Pool 26, Upper Mississippi River, 1891-1989



Data Source:

The 1891 data were derived from 1:20,000-scale Mississippi River Commission Survey base maps. The 1989 data were interpreted from 1:15,000-scale color infrared photographs by the National Ecology Research Center, Fort Collins, CO. The seven classes used were generalized from the original thirteen classes of land cover/land use for each year.

Area Report

	1989		1891	
	Frequency	Acres	Frequency	acres
Open Water	220	12,107	59	16,812
Woody Terrestrial	1,963	13,462	171	21,721
Agriculture	164	38,688	83	22,967
Urban Developed	479	1,379	7	36
Marsh	13	14	0	0
Grasses/Forbs	405	2,390	148	2,917
Sand/Mu	259	837	65	4,424
Totals	3,503	68877	533	68877

EMTC:

The Environmental Management Technical Center administers the Long Term Resource Monitoring Program for the Upper Mississippi River System, performing ecological monitoring and research on the river system.

Figure 7. Changes in land cover/land use, the open river reach, Upper Mississippi River, 1891-1989

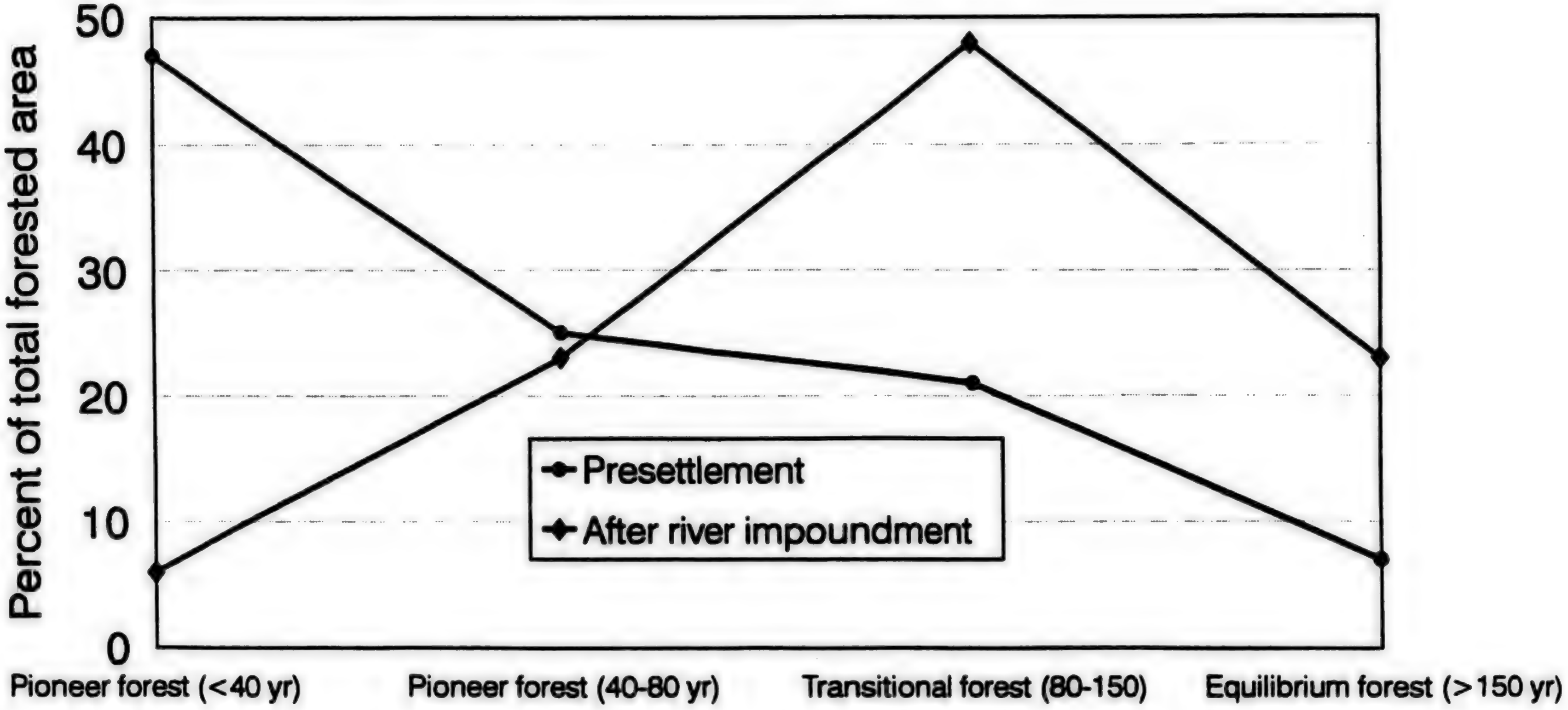


Figure 8. **Changes in forest age structure on the Missouri River floodplain. Data from W. C. Johnson, 1992, Dams and riparian forests: Case study from the Upper Missouri Rivers. Rivers, 3, p. 229-241**

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, D.C. 20503

1. AGENCY USE ONLY (Leave blank)

2. REPORT DATE

February 1995

3. REPORT TYPE AND DATES COVERED

4. TITLE AND SUBTITLE

Modifications of the Upper Mississippi River and Their Effects on Floodplain Forests

5. FUNDING NUMBERS

6. AUTHOR(S)

Yao Yin[1] and John C. Nelson[2]

7. PERFORMING ORGANIZATION NAME AND ADDRESS

[1]The University of Tennessee and National Biological Service, Environmental Management Technical Center,
575 Lester Avenue, Onalaska, Wisconsin 54650
[2]Illinois Natural History Survey, LTRMP Pool 26 Field Station, 4134 Alby Street, Alton, Illinois 62002

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

National Biological Service
Environmental Management Technical Center
575 Lester Avenue
Onalaska, Wisconsin 54650

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

95-T003

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT

Release unlimited. Available from National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161 (call toll free 1-800-553-6847)

12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)

The natural Upper Mississippi River (UMR) and its tributaries flowed and meandered freely across large floodplain landscapes. Processes such as flooding, erosion, and sedimentation were powerful natural forces that shaped and maintained some floodplain forest communities. Beginning in the early nineteenth century, the UMR and its floodplain have been modified by navigation structures and agriculture. As a consequence of human modifications, a large portion of the UMR floodplain is no longer periodically inundated and the hydrologic patterns in the river, as well as on the floodplain, have changed. In general, agriculture and urban development have greatly reduced floodplain forest acres, especially in river reaches where a mainline levee system has been established. Compared to presettlement forest composition, our present floodplain forests are generally less diverse. Silver maple has dramatically increased in abundance and pioneer forests have probably been greatly reduced throughout much of the UMR floodplain.

14. SUBJECT TERMS

Upper Mississippi River, bottomland, floodplain, forest, river, modification, levee, dam

15. NUMBER OF PAGES

17 pp.

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	**18. SECURITY CLASSIFICATION OF THIS PAGE**	**19. SECURITY CLASSIFICATION OF ABSTRACT**	**20. LIMITATION OF ABSTRACT**
Unclassified	Unclassified	Unclassified	

☆ U.S. GOVERNMENT PRINTING OFFICE: 1995-647-973

18

The Long Term Resource Monitoring Program (LTRMP) for the Upper Mississippi River System was authorized under the Water Resources Development Act of 1986 as an element of the Environmental Management Program. The mission of the LTRMP is to provide river managers with information to maintain the Upper Mississippi River System as a sustainable large river ecosystem given its multiple-use character. The LTRMP is a cooperative effort by the National Biological Service, the U.S. Army Corps of Engineers, and the states of Illinois, Iowa, Minnesota, Missouri, and Wisconsin.

END

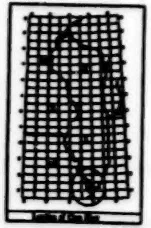
10/24/95

⊞ Marsh

▣ Grasses/Forbs

▧ Sand/Mud

	1989		1891	
	Frequency	Acres	Frequency	acres
Open Water	220	12,107	59	16,812
Woody Terrestrial	1,963	13,462	171	21,721
Agriculture	164	38,688	83	22,967
Urban Developed	479	1,379	7	36
Marsh	13	14	0	0
Grasses/Forbs	405	2,390	148	2,917
Sand/Mu	259	837	65	4,424
Totals	3,503	68877	533	68877



Universal Transverse Mercator Projection,
Zone 15, NAD 27

Cartographer: Melvin L. Bower
September 1994

EMTC:

The Environmental Management Technical Center administers the Long Term Resource Monitoring Program for the Upper Mississippi River System, performing ecological monitoring and research on the river system.

Figure 7. Changes in land cover/land use, the open river reach, Upper Mississippi River, 1891-1989